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(54) **COOLING DEVICE AND CONSTRUCTION MACHINE OR WORKING MACHINE EQUIPPED WITH THE SAME**

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B60H 1/00 (2006.01)
E02F 9/00 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***E02F 9/00*** (2013.01); ***E02F 9/0866*** (2013.01); ***F01P 11/10*** (2013.01); ***F04D 29/164*** (2013.01)

(58) **Field of Classification Search**
CPC B60H 1/00021; B60H 1/00457; B60H 1/00464; B60H 1/00521; B60H 1/242; B60H 1/241; B60H 2001/00078; B60H 2001/006; F01P 5/02; F01P 5/06
USPC 165/41, 47, 121, 44, 51, 122, 123; 415/220, 222, 223
See application file for complete search history.

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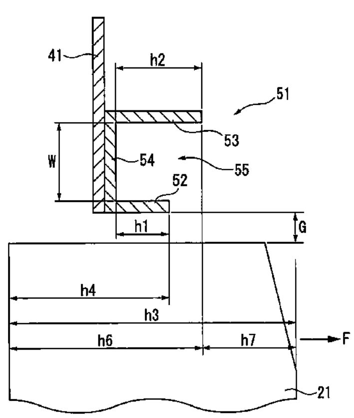
Primary Examiner — Travis Ruby
(74) *Attorney, Agent, or Firm* — Fish & Richardson P.C.

(57) **ABSTRACT**

A cooling device includes: a cooling fan; a shroud provided at an outer circumferential side of the cooling fan; an inner circumferential wall provided on the shroud and adjacent to the outer circumference of the cooling fan so as to surround the cooling fan; an outer circumferential wall provided to surround the inner circumferential wall. An air-flow-direction downstream side end of the outer circumferential wall is positioned at a further downstream position in an air flow direction than an air-flow-direction downstream side end of the inner circumferential wall. The cooling fan is rotatable within a space provided on a radially inner side of the inner circumferential wall. The air-flow-direction downstream side end of the outer circumferential wall is provided at a further upstream position in the air flow direction than an air-flow-direction downstream side end of the cooling fan.

17 Claims, 20 Drawing Sheets



(51) **Int. Cl.**

E02F 9/08	(2006.01)
F01P 11/10	(2006.01)
F04D 29/16	(2006.01)

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U.S. Appl. No. 12/675,140; First Named Inventor: Mitsuo Yabe; Title: "Cooling Device and Construction Machine . . . "; filed Feb. 25, 2010.

U.S. Appl. No. 12/675,145; First Named Inventor: Mitsuo Yabe; Title: "Cooling Device and Construction Machine . . . "; filed Feb. 25, 2010.

Non-final Office Action issued Dec. 1, 2014 from U.S. Appl. No. 12/675,145, 12 pages.

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FIG. 1

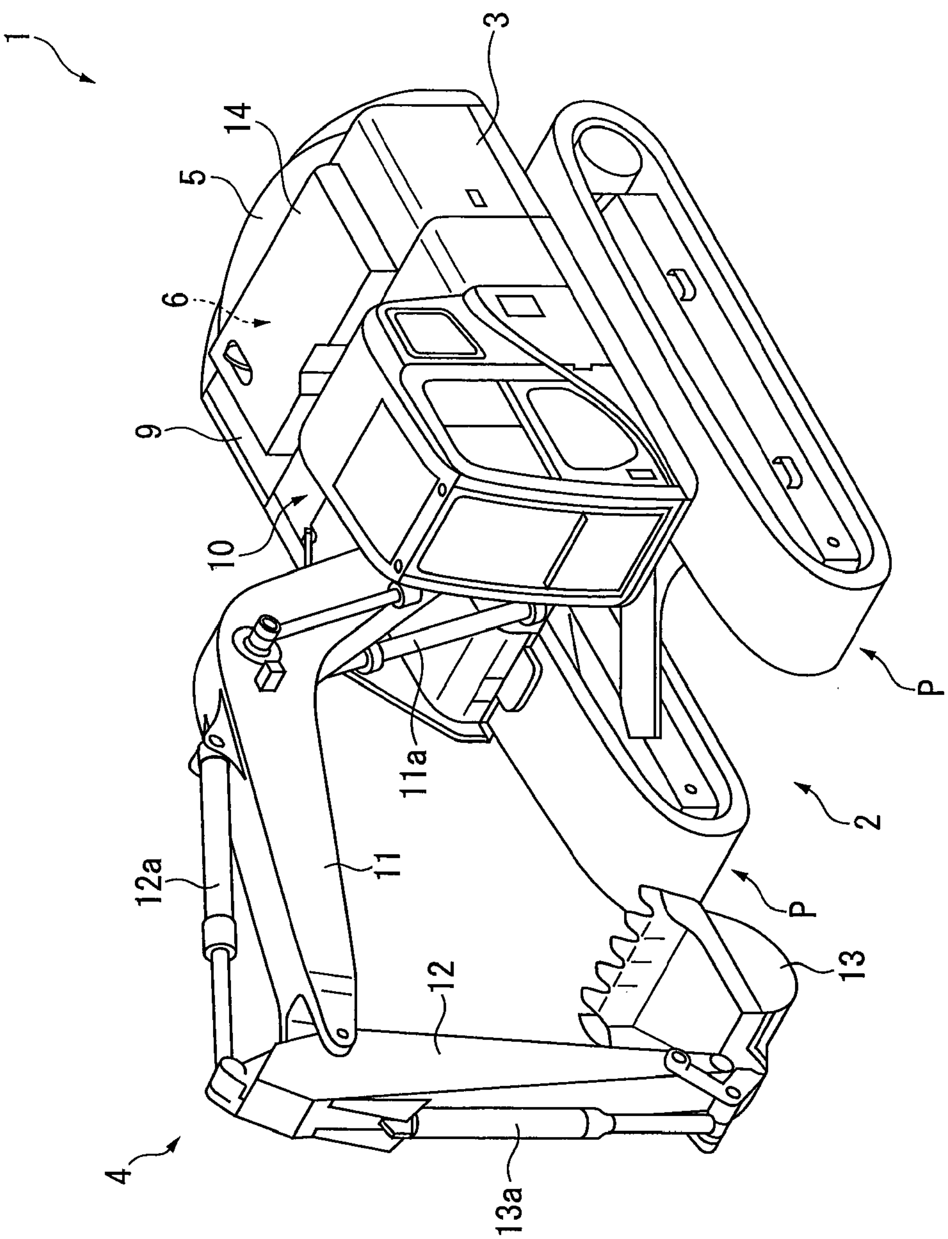


FIG. 2

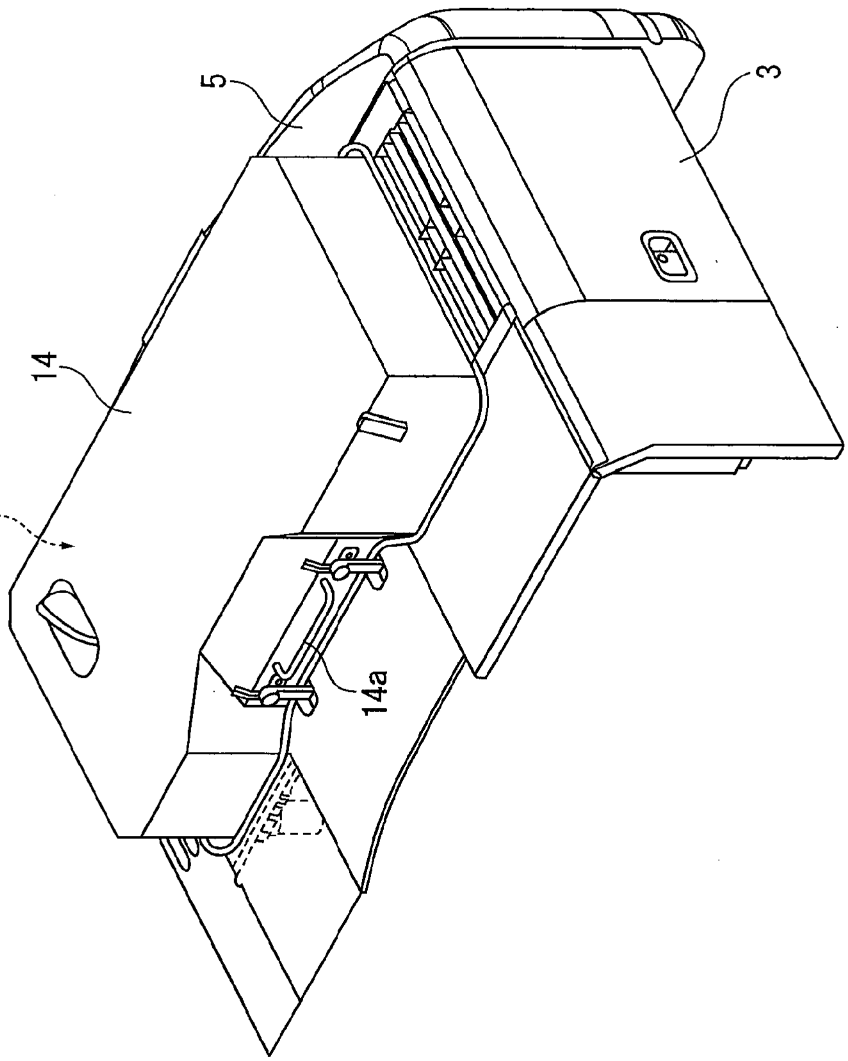


FIG. 3

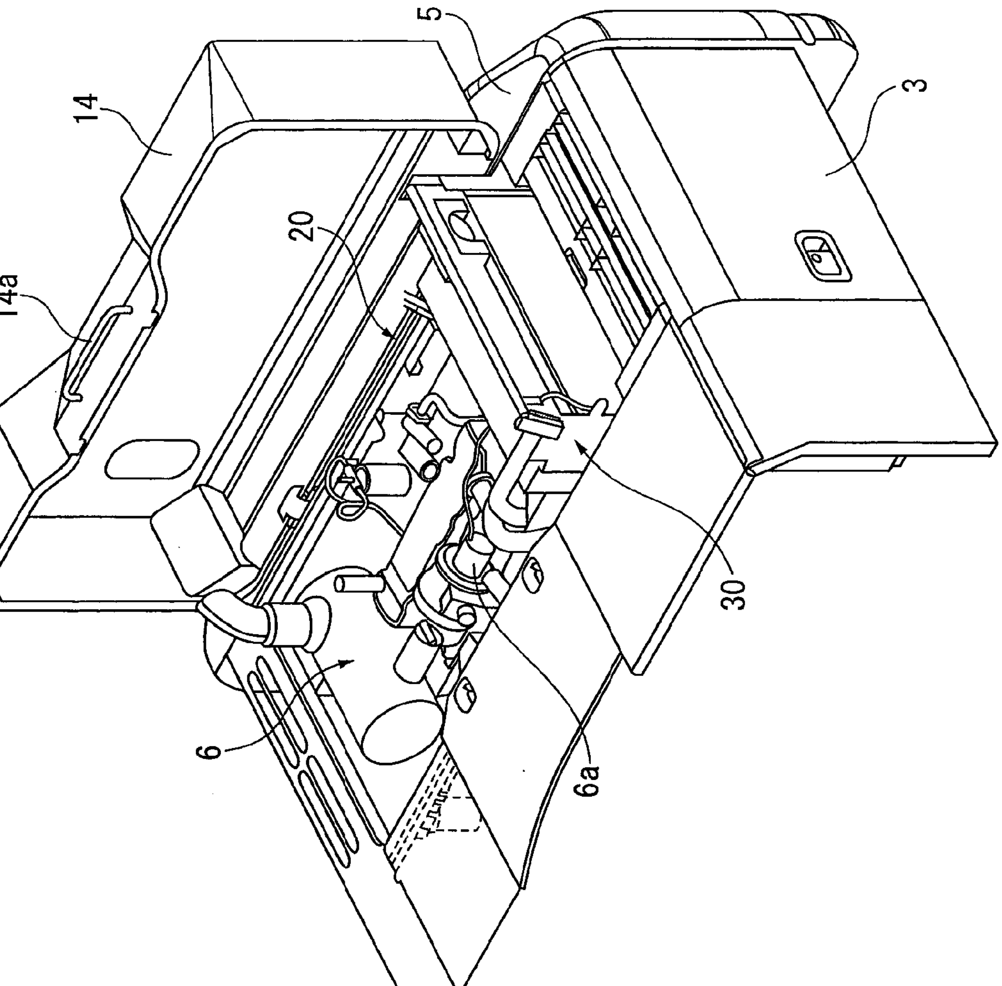


FIG. 4

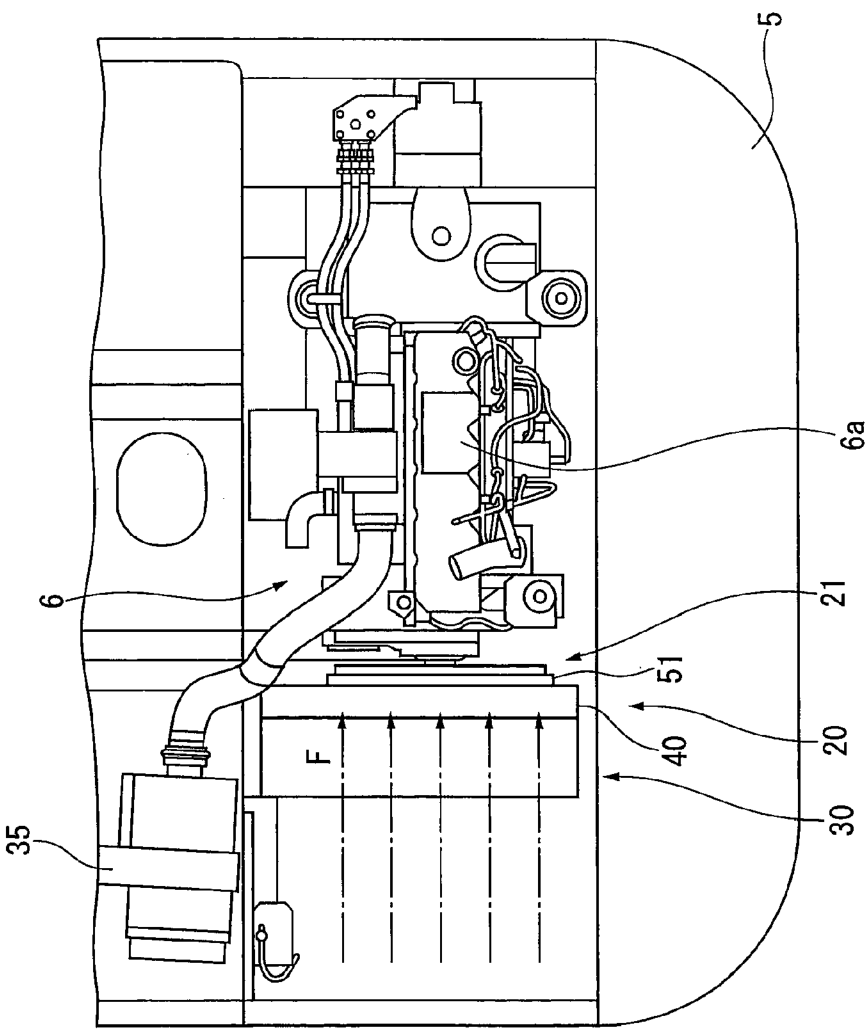


FIG. 5

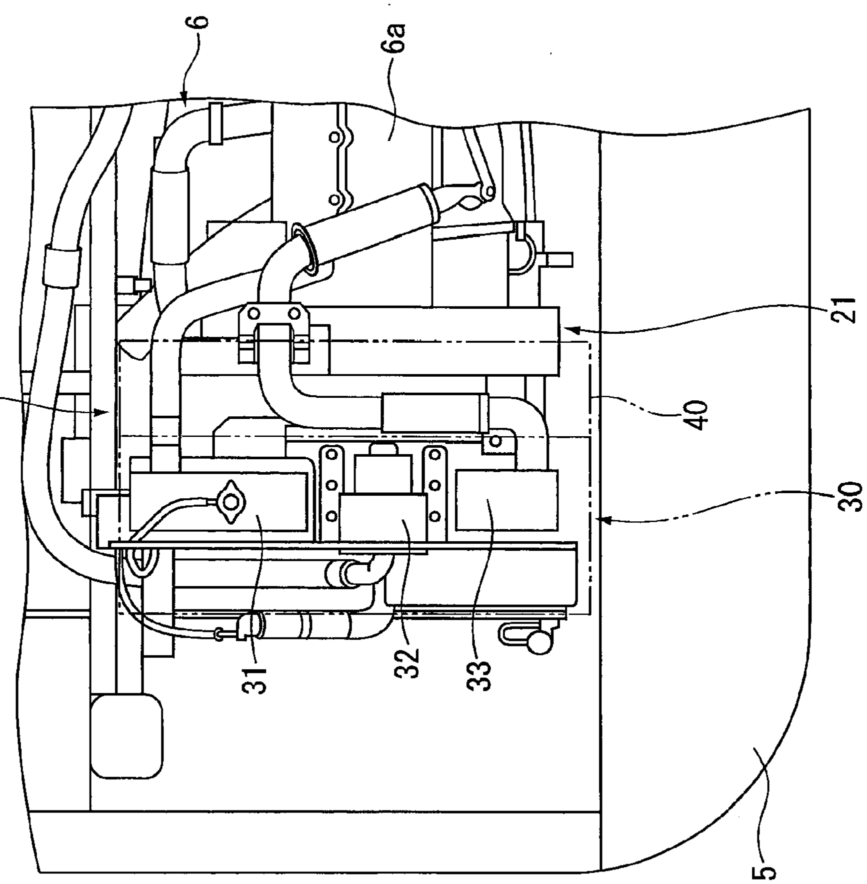


FIG.6

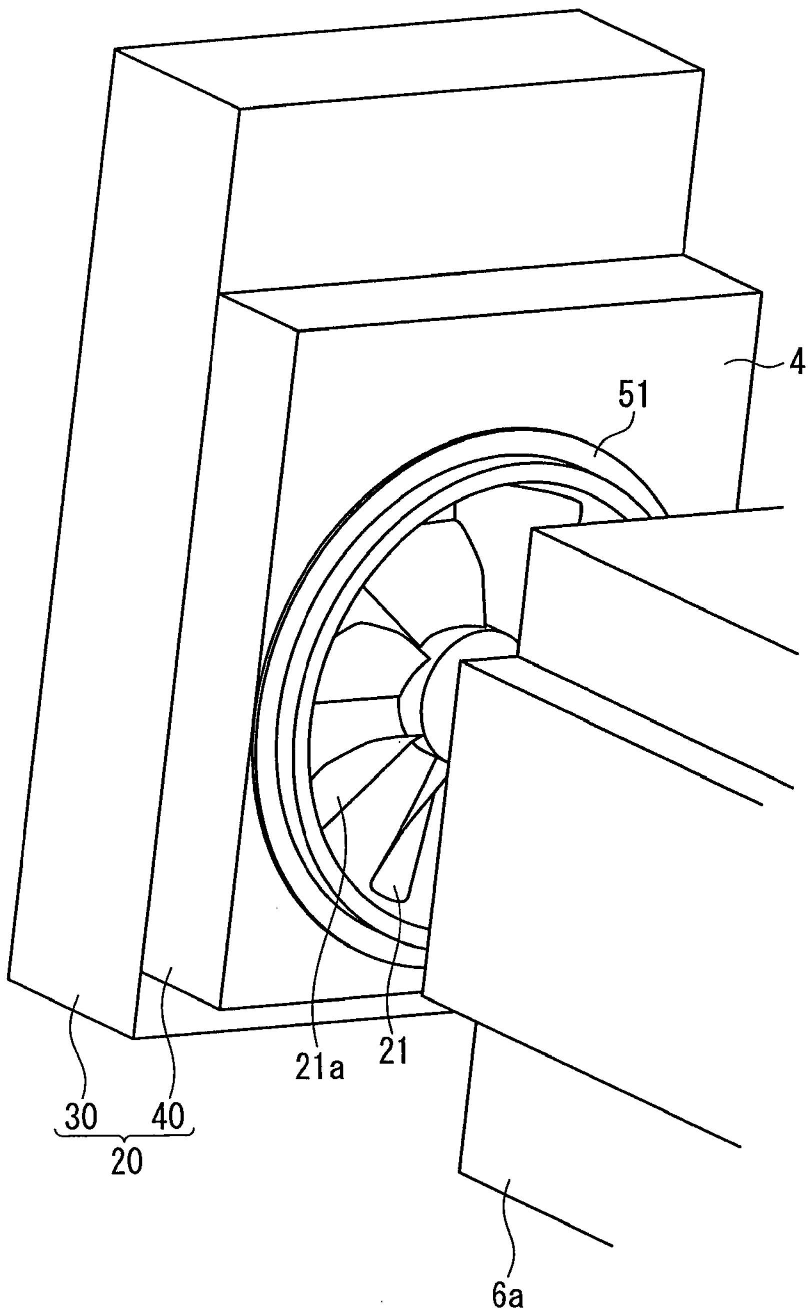


FIG. 7

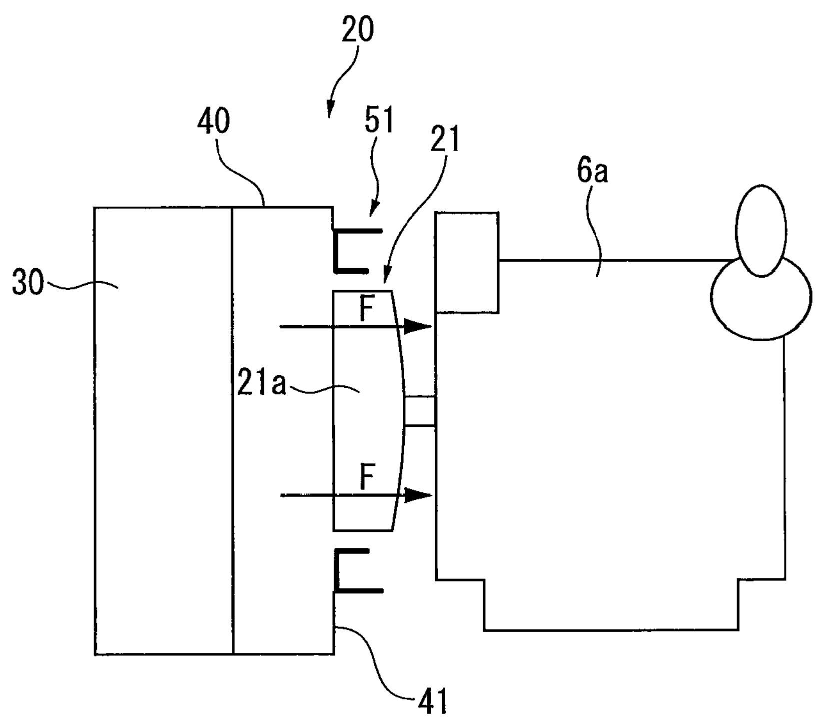


FIG. 8

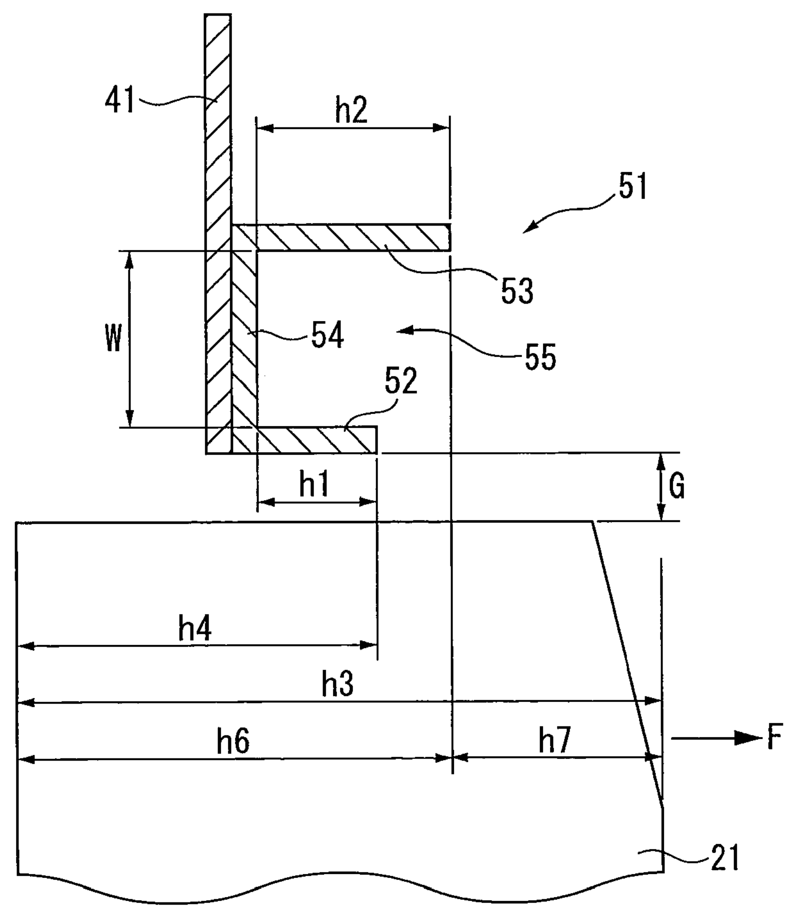


FIG.9

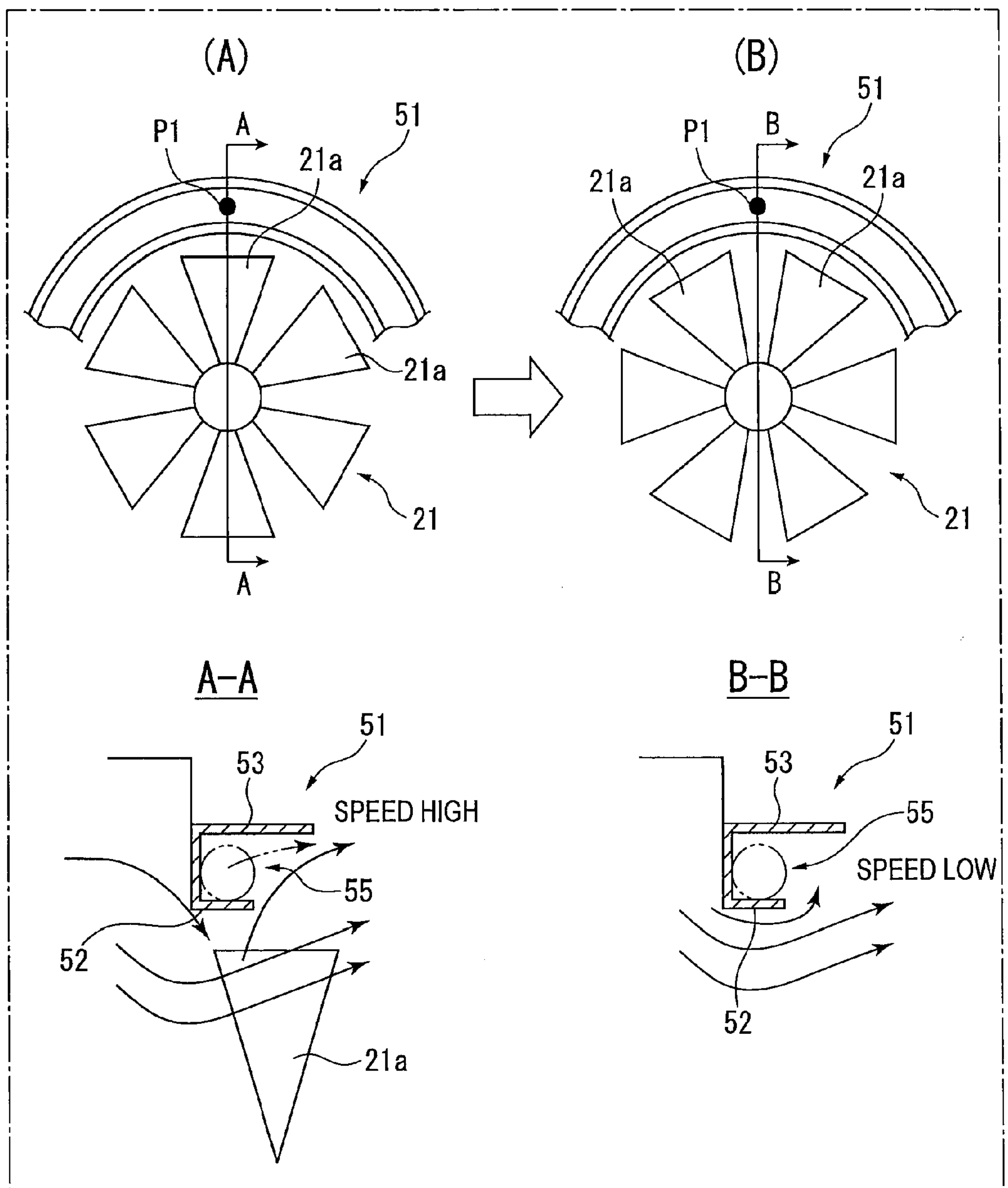

(A)
(B)
P1
A
51
21a
21a
21
A
P1
B
51
21a
21a
21
B
A-A
51
53
SPEED HIGH
55
52
21a
B-B
51
53
55
SPEED LOW
52

FIG. 10

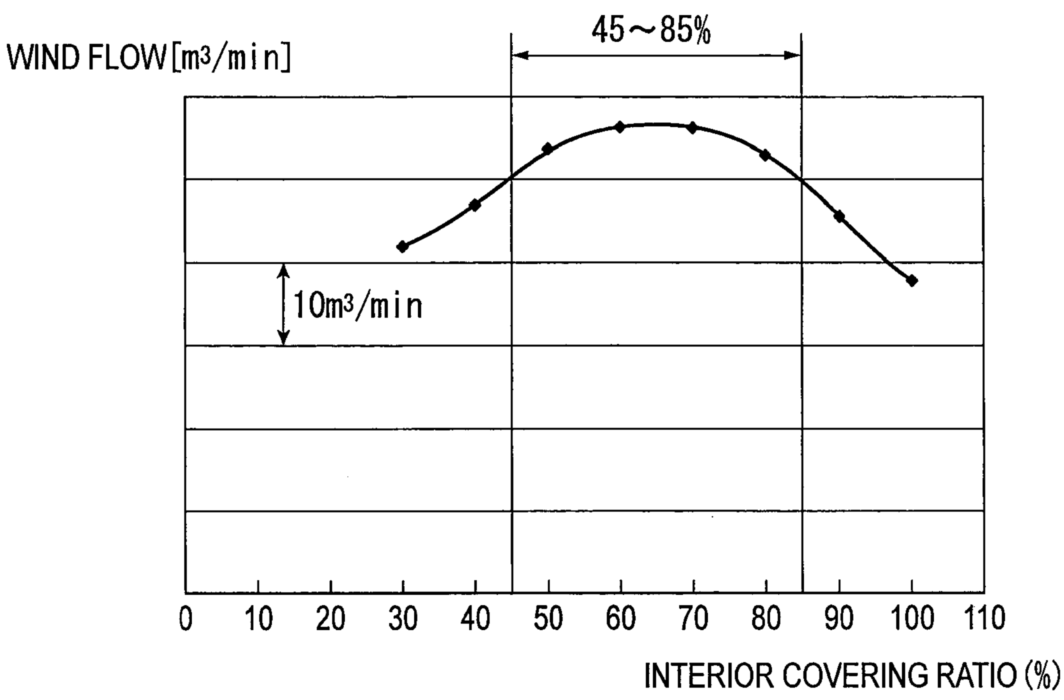

WIND FLOW [m3/min]
45～85%
10m3/min
0
10
20
30
40
50
60
70
80
90
100
110
INTERIOR COVERING RATIO (%)

FIG. 11

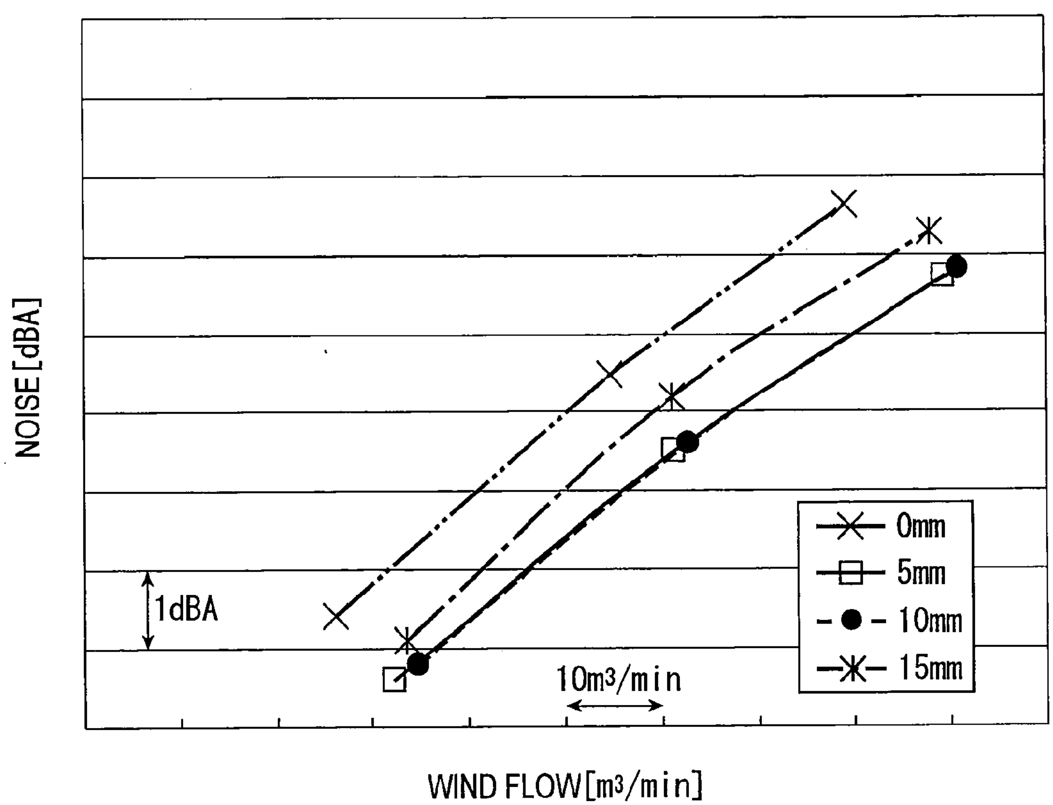


FIG.12

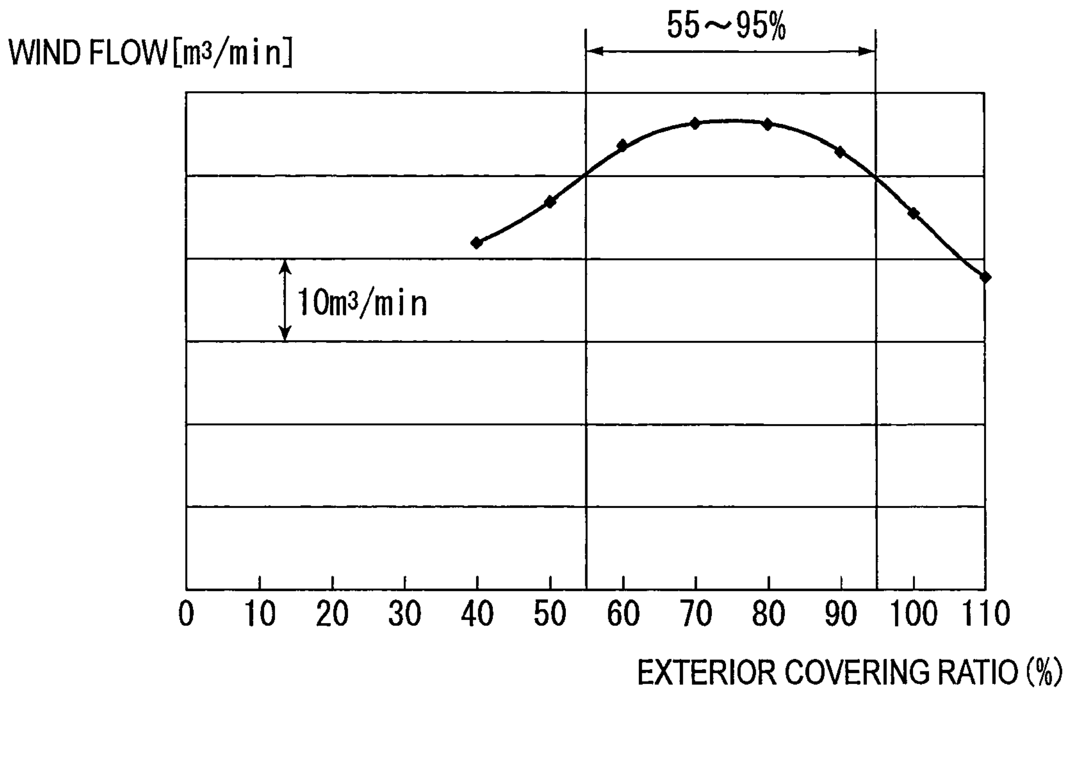
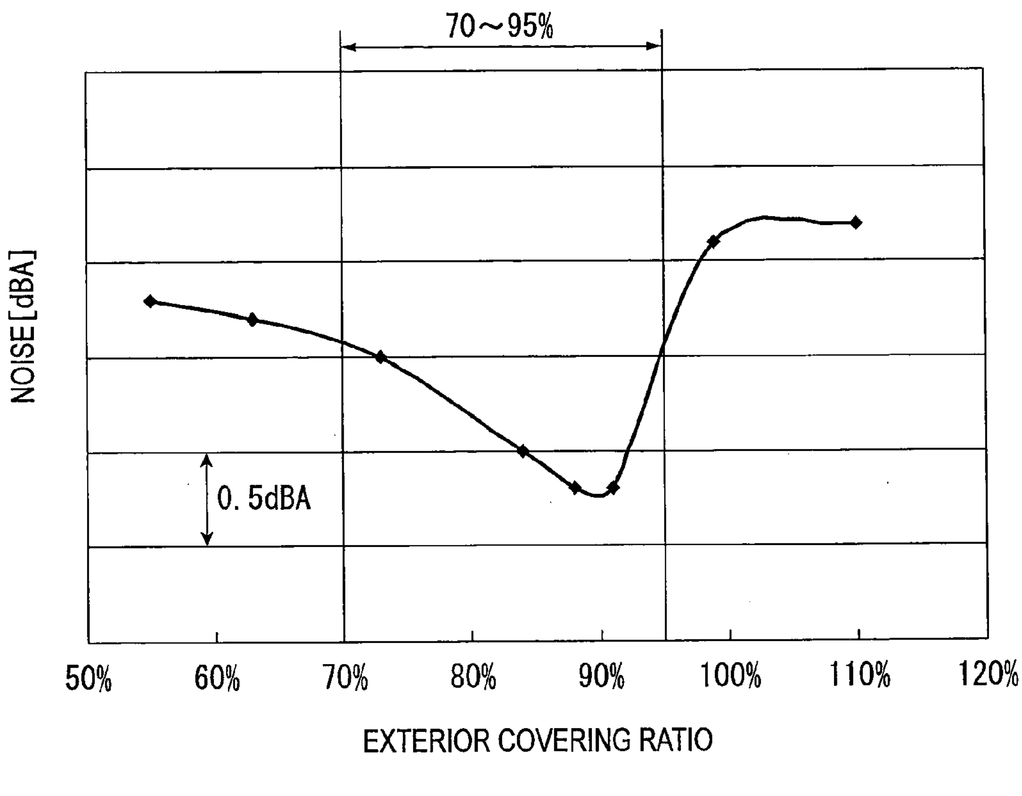

55～95%
WIND FLOW[m3/min]
10m3/min
0 10 20 30 40 50 60 70 80 90 100 110
EXTERIOR COVERING RATIO (%)

FIG. 13



70～95%
NOISE [dBA]
0. 5dBA
50%
60%
70%
80%
90%
100%
110%
120%
EXTERIOR COVERING RATIO

FIG.14A

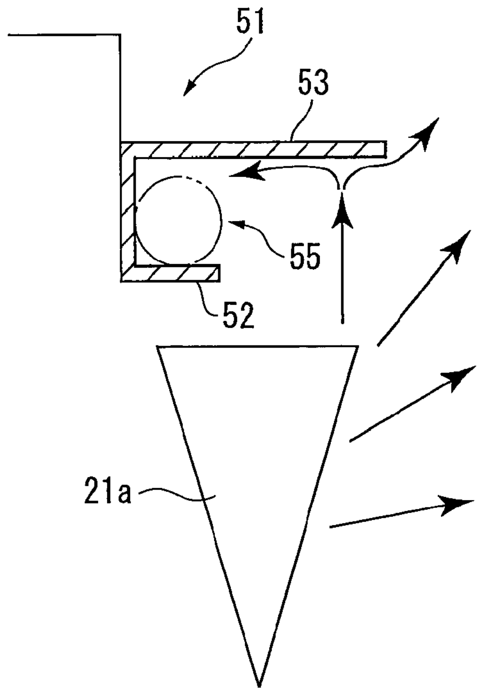


FIG.14B

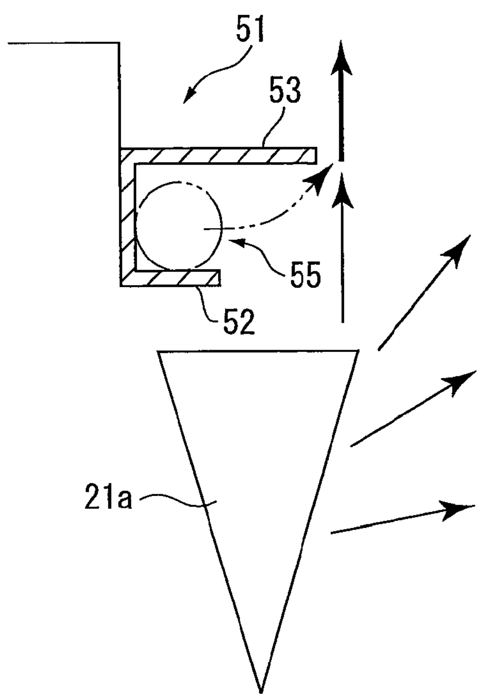


FIG.15

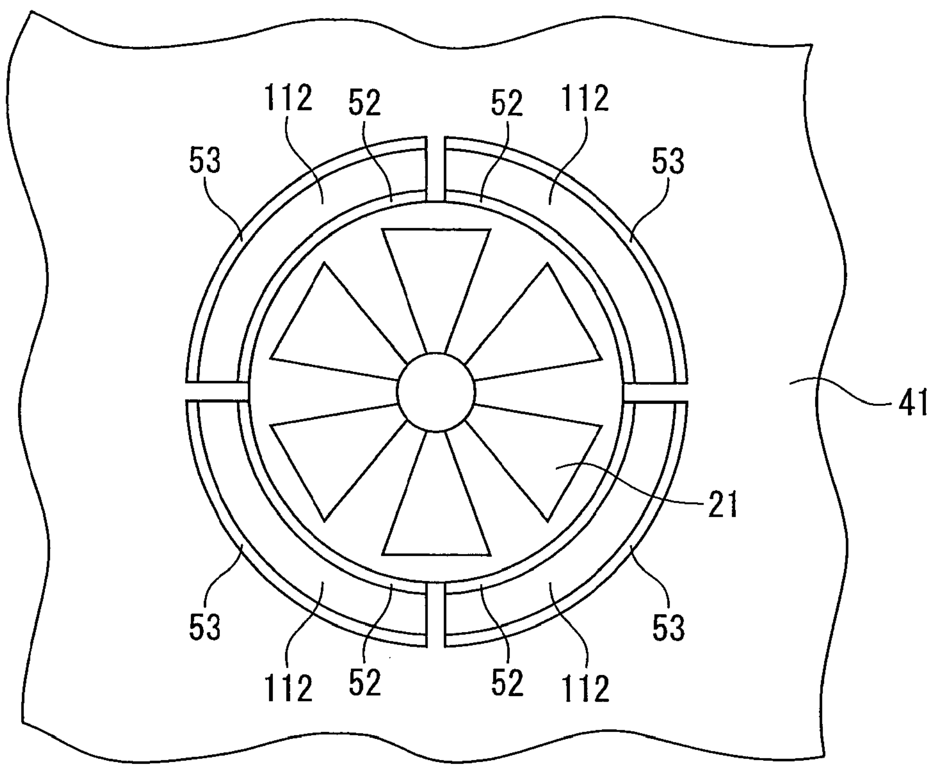


FIG. 16

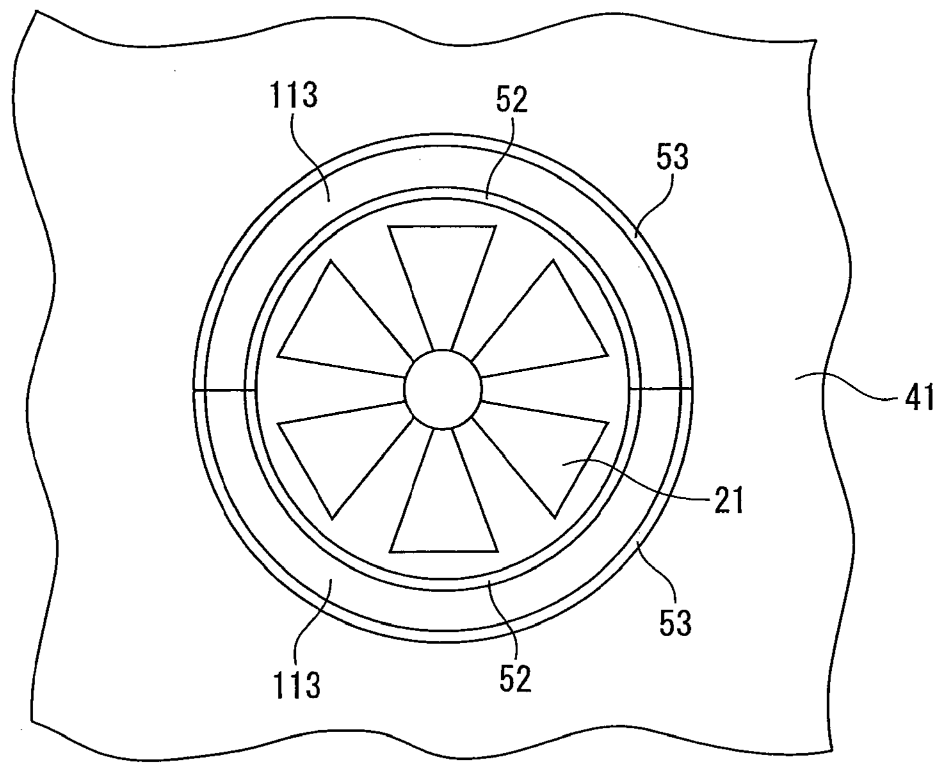


FIG.17

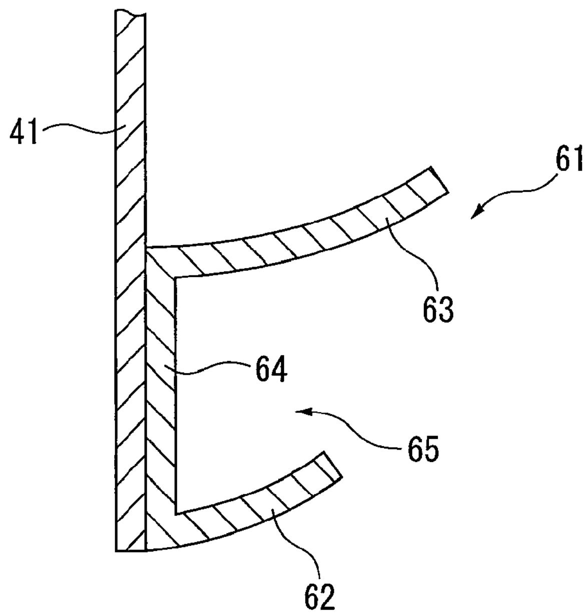


FIG.18

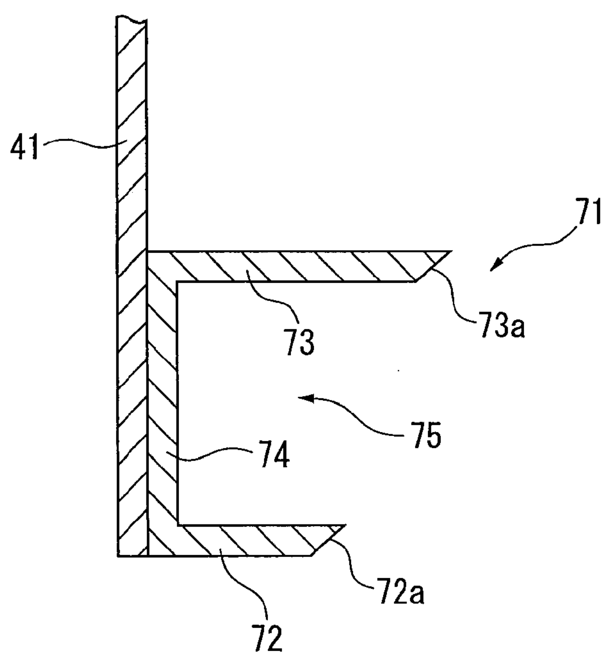


FIG. 19

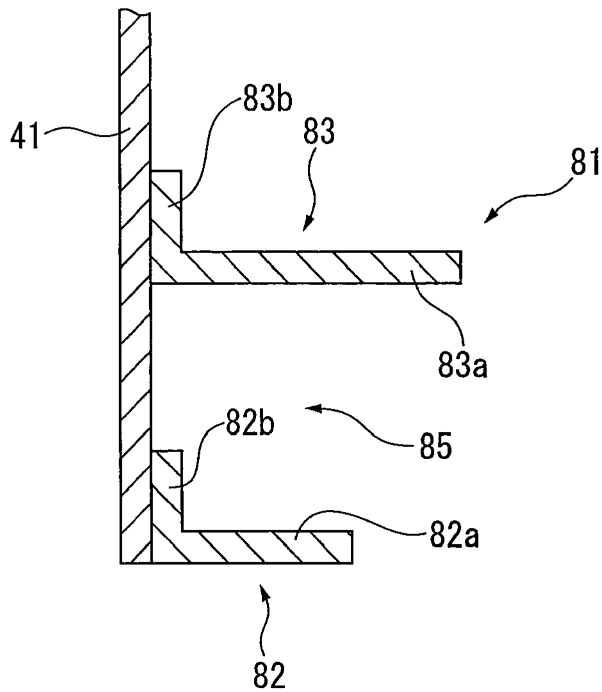


FIG. 20

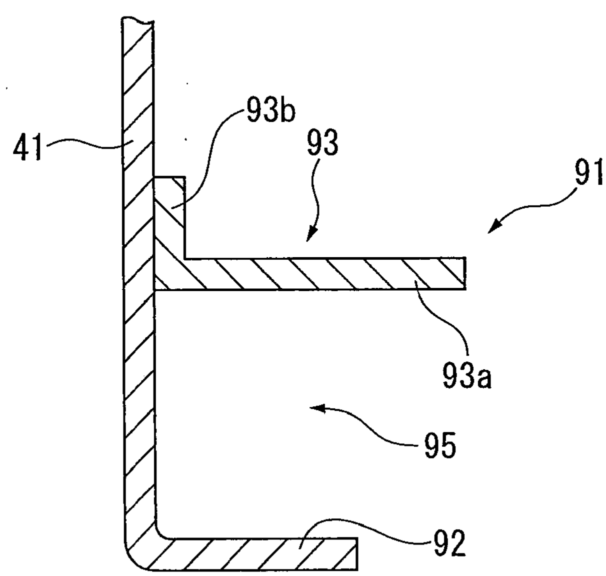


FIG.21

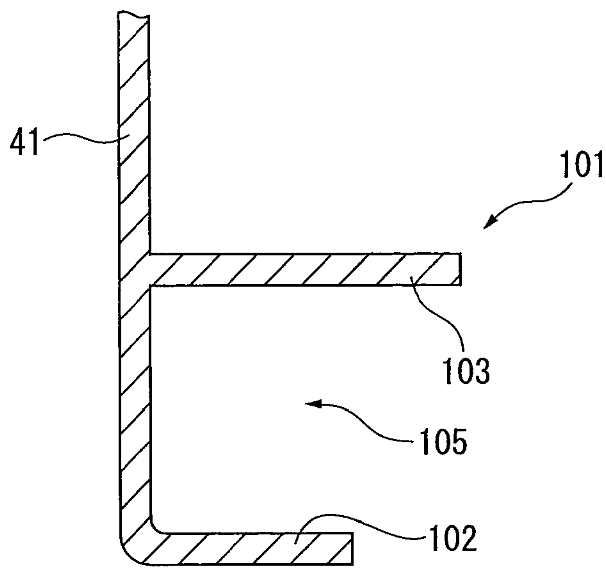
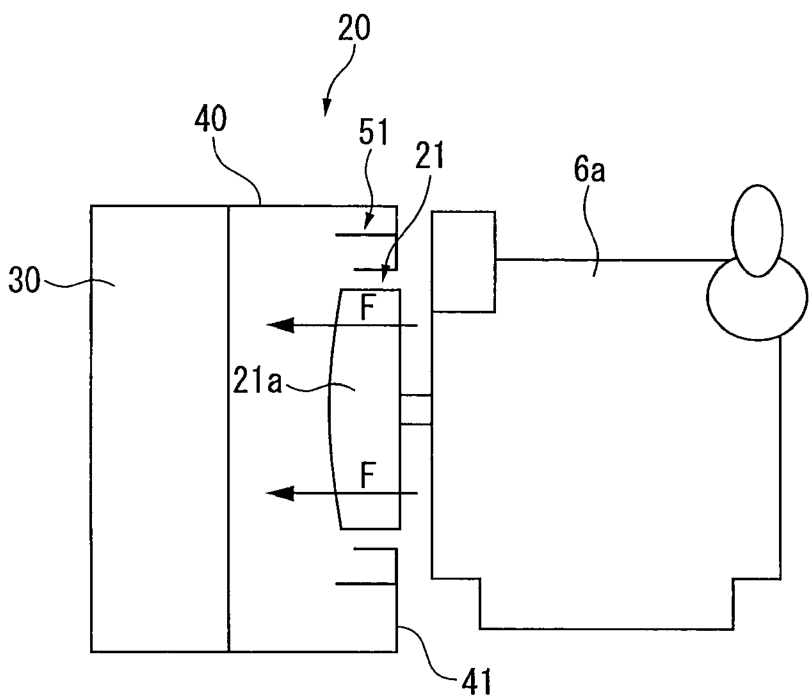


FIG.22



COOLING DEVICE AND CONSTRUCTION MACHINE OR WORKING MACHINE EQUIPPED WITH THE SAME

This application is a U.S. National Phase Application under 35 USC 371 of International Application PCT/JP2008/065539 filed Aug. 29, 2008.

TECHNICAL FIELD

The present invention relates to a cooling device and a construction machine or work machine including the same. More particularly, the present invention relates to a cooling device including a cooling fan and a shroud surrounding the cooling fan, and a construction machine or work machine including the same.

BACKGROUND ART

Traditionally, a cooling system of an engine installed in a construction machine mainly includes a radiator and a cooling fan. The radiator circulates cooling medium between the radiator and the engine and cools the cooling medium by outer air. The cooling fan forms air flow around the radiator and aids heat exchange of the radiator. Further, a shroud is provided between the radiator and the cooling fan to surround the radiator and the cooling fan for ensuring air flow from the radiator to the cooling fan (for example, see Patent Document 1).

In recent years, the total heat quantity of an engine is increased and therefore the water temperature of a radiator is increased. To solve such a problem, for example, the flow of air blown by a cooling fan (i.e., the flow of air passing through the vicinity of the radiator) may be increased by increasing the rotation speed of the cooling fan. However, when the rotation speed of the cooling fan is increased, noise is increased.

Accordingly, to enhance cooling capability of a cooling system of the engine, it is required to increase the flow of air blown by the cooling fan without increasing the rotation speed of the cooling fan. Various technologies for changing a shape and position of a shroud have been developed. For example, to prevent counter flow of air discharged from the cooling fan (i.e., to prevent air in the engine from returning to the radiator through the cooling fan), two cylindrical portions are provided on an end of the shroud (for example, see Patent Document 2).

Patent Document 1: JP-A-9-118141 (Published on May 6, 1997)

Patent Document 2: JP-A-2006-132380 (Published on May 25, 2006)

DISCLOSURE OF THE INVENTION

Problems to be Solved by the Invention

However, according to the cooling system of the engine disclosed in Patent Document 1, the cooling fan is completely accommodated in the shroud. Accordingly, the flow of air discharged from the cooling fan is not sufficiently increased.

Also, according to the cooling system of the engine disclosed in Patent Document 2, the entire cooling fan is provided outside of the shroud. Accordingly, the flow of air discharged from the cooling fan is not rarely affected by the cylindrical portions of the shroud. Thus, the flow of air discharged from the cooling fan is not sufficiently increased.

An object of the invention is to provide a cooling device capable of sufficiently increasing flow of air from a cooling fan without increasing rotation speed of the cooling fan, and to provide a construction machine or work machine equipped with the cooling device.

Means for Solving the Problems

A cooling device according to an aspect of the invention includes: a cooling fan; a shroud provided at an outer circumferential side of the cooling fan; an inner circumferential wall provided on the shroud and adjacent to the outer circumference of the cooling fan so as to surround the cooling fan; and an outer circumferential wall provided to surround the inner circumferential wall, an air-flow-direction downstream side end of the outer circumferential wall being positioned at a further downstream position in an air flow direction than an air-flow-direction downstream side end of the inner circumferential wall, in which the cooling fan is rotatable in a space on a radially inner side of the inner circumferential wall, and the air-flow-direction downstream side end of the outer circumferential wall is positioned at a further upstream position in the air flow direction than an air-flow-direction downstream side end of the cooling fan.

The inner circumferential wall and the outer circumferential wall may be provided by arranging a plurality of members around a rotation shaft of the cooling fan. However, it is preferable that at least either one of the inner circumferential wall and the outer circumferential wall is a ring that is consecutively provided around the rotation shaft of the cooling fan.

In the cooling device according to the aspect of the invention, when the cooling fan is rotated and an air flow is generated, a negative pressure generated in a space between the inner circumferential wall and outer circumferential wall of the ring suctions the air into the space, or the suctioned air is swept out from the space. With this arrangement, the flow of air blown by the cooling fan is increased. Thus, cooling capability is enhanced even when the rotation speed of the cooling fan remains the same as conventional. Even when the rotation speed of the cooling fan is reduced, the same cooling capability can be obtained.

Preferably in the cooling device according to the aspect of the invention, an exterior covering ratio is in a range of 55 to 95%, the exterior covering ratio being defined as a ratio between: an air-flow-direction length of a portion covered by the shroud and the outer circumferential wall; and a maximum air-flow-direction length of the cooling fan in the air flow direction of the cooling fan. The exterior covering ratio is more preferably 70 to 95%, further more preferably 70 to 80%.

Since the exterior covering ratio is set in the range of 55 to 95% in the cooling device according to the aspect of the invention, the flow of air blown by the cooling fan is sufficiently increased. Thus, cooling capability is enhanced even when the rotation speed of the cooling fan remains the same as conventional. Even when the rotation speed of the cooling fan is reduced, the same cooling capacity can be obtained. It is more preferable that the exterior covering ratio is 70 to 95% to reduce the noise. It is also more preferable that the exterior covering ratio is 70 to 80% to enhance the cooling capability by increasing the wind flow.

Preferably in the cooling device according to the aspect of the invention, an interior covering ratio is in a range of 45 to 85%, the interior covering ratio being defined as a ratio between: an air-flow-direction length of a portion covered by the shroud and the inner circumferential wall; and a maximum air-flow-direction length of the cooling fan in the air flow direction of the cooling fan.

Since the interior covering ratio is set in the range of 45 to 85% in the cooling device according to the aspect of the invention, the flow of air blown by the cooling fan is sufficiently increased. Thus, cooling capability is enhanced even when the rotation speed of the cooling fan remains the same as conventional. Even when the rotation speed of the cooling fan is reduced, the same cooling capability can be obtained.

Preferably in the cooling device according to the aspect of the invention, at least one of the inner circumferential wall and the outer circumferential wall may be integrated with the shroud.

To integrally form at least either one of the inner circumferential wall and the outer circumferential wall with the shroud, at least either one of the shroud and the inner circumferential wall and outer circumferential wall may be made of resin and formed integrally by injection molding.

In such a cooling device, the load of assembling work can be reduced by reduction of the number of parts because at least one of the inner circumferential wall and the outer circumferential wall is integrated with the shroud.

Preferably in the cooling device according to the aspect of the invention, at least one of the inner circumferential wall and the outer circumferential wall is formed by a member different from the shroud.

In such a cooling device, the inner circumferential wall and the outer circumferential wall can be appropriately selected suitably for the arrangement of the shroud and the cooling fan because at least either one of the inner circumferential wall and the outer circumferential wall is attachable to the shroud.

The cooling device according to the aspect of the invention preferably further includes an annular base connecting the inner circumferential wall to the outer circumferential wall.

It is easy to manufacture and manage such a cooling device owing to the use of single integrated member formed by the inner circumferential wall, the outer circumferential wall and the base.

Preferably in the cooling device according to the aspect of the invention, at least one of the inner circumferential wall and the outer circumferential wall includes a cylindrical portion extending in parallel to the air flow direction.

According to such a cooling device, it is easy to manufacture the inner circumferential wall and the outer circumferential wall because at least one of the inner circumferential wall and the outer circumferential wall has a cylindrical portion extending in parallel to the air flow direction.

Preferably in the cooling device according to the aspect of the invention, at least one of the inner circumferential wall and the outer circumferential wall includes a diameter-expanded portion of which an inner diameter increases toward downstream in the air flow direction.

Since at least one of the inner circumferential wall and the outer circumferential wall has the diameter-expanded portion in such a cooling device, the flow of air blown by the cooling fan is sufficiently increased.

A construction machine or a work machine according to another aspect of the invention includes any one of the above-described cooling devices.

Since the construction machine or the work machine includes the cooling device capable of enhancing the cooling efficiency, the construction machine or the work machine can ensure a highly quiet operation by reducing operational noise generated by the cooling fan.

In the cooling device according to the aspect of the invention, the flow of air blown by the cooling fan can be sufficiently increased without increasing the rotation speed of the cooling fan.

BRIEF DESCRIPTION OF DRAWINGS

FIG. **1** is an overall view showing a hydraulic excavator including a shroud structure of a cooling fan according to an exemplary embodiment of the invention.

FIG. **2** is a perspective view showing an arrangement in the vicinity of an engine room and a counterweight mounted on a rear side of the hydraulic excavator.

FIG. **3** is a perspective view showing an engine hood in an open state, the engine hood provided on an upper surface of the engine room shown in FIG. **2**.

FIG. **4** is a plain view showing an arrangement within the engine hood shown in FIG. **3**.

FIG. **5** is a partially enlarged view of FIG. **4**.

FIG. **6** is a perspective view showing an arrangement of a cooling unit.

FIG. **7** schematically shows a relationship of an engine and the cooling unit.

FIG. **8** is a cross-sectional view showing a positional relationship of a ring and an outer circumference of the cooling fan.

FIG. **9** is a schematic view for explaining effect of increase in wind flow by the ring.

FIG. **10** is a graph showing a relationship between an interior covering ratio and a wind flow.

FIG. **11** is a graph showing a relationship between air-flow-direction lengths of an inner circumferential wall and an outer circumferential wall, wind flow and noise.

FIG. **12** is a graph showing a relationship between an exterior covering ratio and wind flow.

FIG. **13** is a graph showing a relationship between an exterior covering ratio and noise.

FIG. **14**A is a schematic view for explaining a positional relationship between an air-flow-direction downstream side end of the cooling fan and an air-flow-direction downstream side end of the outer circumferential wall and the principle of generation of negative pressure.

FIG. **14**B is a schematic view for explaining the positional relationship between the air-flow-direction downstream side end of the cooling fan and the air-flow-direction downstream side end of the outer circumferential wall and the principle of generation of negative pressure.

FIG. **15** is a front view showing an arrangement of an inner circumferential wall and an outer circumferential wall of a cooling fan according to a second exemplary embodiment of the invention.

FIG. **16** is a front view showing an arrangement of a ring according to another exemplary embodiment.

FIG. **17** is a cross-sectional view showing an arrangement of a ring according to another exemplary embodiment.

FIG. **18** is a cross-sectional view showing an arrangement of a ring according to another exemplary embodiment.

FIG. **19** is a cross-sectional view showing an arrangement of a ring according to another exemplary embodiment.

FIG. **20** is a cross-sectional view showing an arrangement of a ring according to another exemplary embodiment.

FIG. **21** is a cross-sectional view showing an arrangement of a ring according to another exemplary embodiment.

FIG. **22** schematically shows a relationship between an engine and a cooling unit when the invention is applied to a blowoff cooling unit.

BEST MODE FOR CARRYING OUT THE INVENTION

As an exemplary embodiment of the invention, a hydraulic excavator (construction machine) **1** including a cooling unit **20** (a cooling device according to the aspect of the invention) will be described below with reference to the accompanying drawings.

First Exemplary Embodiment

Entire Arrangement of Hydraulic Excavator 1

As shown in FIG. **1**, a hydraulic excavator **1** according to a first exemplary embodiment includes: an undercarriage **2**; a swing frame **3**; a working equipment **4**; a counterweight **5**; an engine room **6**; an equipment enclosure **9**; a cab **10**; and a cooling unit **20** (see FIG. **3**).

The undercarriage **2** moves the hydraulic excavator **1** forward and backward by rotating crawler belts P wound around right and left ends in the traveling direction while carrying the swing frame **3** in a manner swingable on an upper surface of the undercarriage **2**.

The swing frame **3** is swingable in any direction on the undercarriage **2**. The working equipment **4**, counterweight **5**, engine room **6** and cab **10** are provided on an upper surface of the swing frame **3**.

The working equipment **4** includes: a boom **11**; an arm **12** provided on an end of the boom **11**; and a bucket **13** provided on an end of the arm **12**. The working equipment **4** is used to excavate gravel and sand at a site of civil engineering works by moving the boom **11**, arm **12** and bucket **13** up and down using hydraulic cylinders **11***a*, **12***a* and **13***a* included in a hydraulic circuit (not shown).

The counterweight **5**, which is made by solidifying scrap iron and concrete poured into a box formed by steel plates, is provided on a rear side of the engine room **6** on the swing frame **3** to balance the vehicle body during mining.

As shown in FIGS. **2** and **3**, the engine room **6** is adjacent to the counterweight **5**. The engine room **6** has an upper opening for inspection covered by an engine hood **14** openable and closable by a grab **14***a*. The engine room **6** accommodates a cooling unit **20** including: an engine **6***a* as a power source for driving the undercarriage **2** and the working equipment **4**; and a cooling core **30** (see FIG. **3**).

The equipment enclosure **9** is provided on a rear side of the working equipment **4** and includes a fuel tank, hydraulic oil tank and operation valve (not shown) therein.

The cab **10**, which is a room for an operator of the hydraulic excavator **1**, is provided on a front and left side on the swing frame **3** (a side of the working equipment **4**) so that the operator can see a distal end of the working equipment **4**.

As shown in FIG. **4**, the cooling unit **20** is adjacent to the engine **6***a* in the engine room **6** to cool cooling water and hydraulic oil flowing through the engine **6***a*. The arrangement of the cooling unit **20** will be described later in detail.

[Cooling Unit **20**]

As shown in FIGS. **3** and **4**, the cooling unit **20** includes a cooling fan **21** and the cooling core **30**. The cooling unit **20** also includes the later-described shroud **40** (see FIG. **6**) to send a large volume of air to the cooling core **30** for efficient cooling while reducing the noise.

As shown in FIG. **6**, the cooling fan **21** is directly connected to the engine **6***a*. Vanes **21***a* (see FIG. **6**) are rotated directly by the engine **6***a*. In this exemplary embodiment, when the cooling fan **21** is driven, air flows in a direction where the cooling fan **21** suctions the air as arrows F in FIGS. **4**, **7** and **8** indicate. In other words, the cooling fan **21** is located on the downstream side of the cooling core **30** in the air flow generated by the cooling fan **21**. The arrangement of the cooling fan **21** will be described later in detail. Hereinafter, the direction indicated by the arrows F in FIGS. **4**, **7** and **8** will be referred to as an air flow direction. The left side and right side in FIGS. **4**, **7** and **8** will be referred to respectively as an upstream side and a downstream side.

The cooling core **30** is a unit for cooling the cooling medium by heat exchange with air. As shown in FIG. **5**, the cooling core **30** includes a radiator **31**, an oil cooler **32** and an aftercooler **33**.

The radiator **31** reduces the temperature of cooling water flowing through the engine **6***a* by heat exchange between the cooling water and air generated by the cooling fan **21**.

The oil cooler **32** reduces the temperature of oil to be delivered to the hydraulic cylinders **11***a*, **12***a* and **13***a* by heat exchange between oil supplied from the hydraulic oil tank to the hydraulic circuit and heated and air generated by the cooling fan **21**.

The aftercooler **33** cools the heated air by heat exchange between air suctioned from an air cleaner **35** and discharged from a turbocharger (not shown) of the engine **6***a* and air generated by the cooling fan **21**, and then delivers the cooled air to an intake manifold (not shown) of the engine **6***a*.

[Cooling Fan **21**]

The cooling fan **21** is an axial-flow fan having a plurality of vanes **21***a* rotatable around a rotation shaft and driven by the engine **6***a*. The number of the vanes **21***a* depends on an airflow volume and a size of the cooling fan **21**. Typically, the number of the vanes **21***a* is approximately 6 to 11.

The vanes **21***a* are rotated by the engine **6***a*. By rotating the plurality of vanes **21***a*, the generated air flow flows radially outward from the rotation shaft.

As shown in FIGS. **6** to **8**, the shroud **40** covers an outer circumference of the vanes **21***a* of the cooling fan **21** and includes a case **41**. The case **41** is a plate-shaped member having a circular opening conformed to the outer circumference of the vanes **21***a*.

A ring **51** is fixed to an inner circumference of the case **41**. The ring **51**, which is for increasing the flow of air blown by the cooling fan **21**, is made of sheet-metal or resin.

As shown in FIG. **8**, the ring **51** includes an inner circumferential wall **52**, an outer circumferential wall **53** and a base **54**.

The inner circumferential wall **52** is positioned on an edge of the opening of the case **41** and is adjacent to an outer circumferential edge of (the vanes **21***a* of) the cooling fan **21**. The diameter of the inner circumferential wall **52** is larger than the outer diameter of the cooling fan **21**. A clearance G between the inner circumferential wall **52** and the cooling fan **21** is, for example, 15 mm.

The outer circumferential wall **53** is positioned at a further radially outward position than the inner circumferential wall **52** to surround the inner circumferential wall **52**. An annular space **55** is provided therebetween. The inner circumferential wall **52** and the outer circumferential wall **53** are concentrically-positioned cylindrical members and extend in parallel in the air flow direction.

In the first exemplary embodiment, no bore is formed on the inner circumferential wall **52** or the outer circumferential wall **53**. An air-flow-direction length h1 of the inner circumferential wall **52** is smaller than an air-flow-direction length h2 of the outer circumferential wall **53**. In other words, an air-flow-direction downstream side end of the outer circumferential wall **53** is positioned at a further downstream position in the air flow direction than an air-flow-direction downstream side end of the inner circumferential wall **52**.

The base **54** is annular and flat to connect the outer circumferential wall **53** with the inner circumferential wall **52**. As described above, the ring **51** is a single member and attachable to the case **41**. The ring **51** may include fixed portions (not shown). For example, the fixed portions may be projections extending radially outward from the base at a plurality of positions in the circumferential direction. The ring **51** may be fixed to the case **41** by weld, adhesion or any other fixing member.

In the first exemplary embodiment, the air-flow-direction length h1 of the inner circumferential wall **52** is 20 mm, the air-flow-direction length h2 of the outer circumferential wall **53** is 30 mm, and a width W of the base **54** is 30 mm. However, the invention is not limited to these numerical values.

Next, a positional relationship of the cooling fan **21** and the ring **51** will be described below. As shown in FIG. **8**, the outer circumferential edge of the cooling fan **21** is positioned at a further downstream position in the air flow direction than the inner circumferential wall **52** of the ring **51**.

More specifically, the air-flow-direction downstream side end of the outer circumferential edge of the cooling fan **21** is positioned at a further downstream position in the air flow direction than the air-flow-direction downstream side end of the inner circumferential wall **52**.

An air-flow-direction length of the cooling fan **21** will be referred to as h3. An air-flow-direction length of an upstream portion of the cooling fan **21**, which is positioned at a further upstream position than the end of the inner circumferential wall **52**, will be referred to as h4.

A percentage of h4/h3 will be referred to as an "interior covering ratio (%)." For example, the interior covering ratio is 62.5% in the first exemplary embodiment.

[Cooling Operation]

When the cooling fan **21** is driven by the engine **6***a*, air in the vicinity of the cooling core **30** is suctioned into the cooling fan **21**. This flow of the air cools down the radiator **31** and the like of the cooling core **30**.

As shown in FIG. **9** (A), when a vane **21***a* of the cooling fan **21** passes through a position P**1** in the space **55** (an observation point in FIG. **9**), air in the vicinity of the P**1** is swept out by flow of air from the vane **21***a*, such that negative pressure is generated at the P**1**. Next, as shown in FIG. **9** (B), when the P**1** in the space **55** (the observation point in FIG. **9**) is positioned between vanes **21***a* of the cooling fan **21**, the negative pressure generated at the P**1** suctions the air and suppresses the generation of vortex. Due to such a phenomenon, flow of air blown by the cooling fan **21** is considerably increased as compared with a conventional arrangement.

Consequently, an amount of air supplied to the cooling core **30** is increased, so that cooling efficiency can be enhanced.

With such an arrangement according to the aspect of the invention, the negative pressure generated in the space **55** can suppress the generation and growth of Karman vortex, and thus the noise is considerably reduced as compared to a conventional arrangement. Accordingly, even when the rotation speed of the cooling fan **21** is increased to be more than the rotation speed of a conventional cooling fan, the noise is still in a tolerable range.

Especially, in this exemplary embodiment, since the air-flow-direction downstream side end of the cooling fan **21** is positioned at a further downstream position in the air flow direction than the air-flow-direction downstream side end of the inner circumferential wall **52** of the ring **51**, the flow of air is further increased due to the above-described phenomenon. This is presumably because air in the space **55** can be more effectively swept out when the vane **21** passes by in the above-described structure.

[Relationship Between Covering Ratio and Wind Flow]

Initially, the interior covering ratio of the inner circumferential wall **52** was changed in the cooling fan **21** having the same rotation speed to measure the change of flow of air blown by the cooling fan **21**. When the interior covering ratio was 100%, the wind flow was small as shown in FIG. **10**. The wind flow was gradually increased as the interior covering ratio was reduced. The wind flow reached its peak when the interior covering ratio was appropriately 60 to 70%. When the interior covering ratio was further reduced, the wind flow was reduced. When the interior covering ratio was less than 45% or more than 85%, the wind flow was almost equal to the wind flow exhibited when the interior covering ratio was 100%. In FIG. **10**, a scale unit of the vertical axis of the graph is 10 m^3/min.

From the above, it was found that a sufficient wind flow was obtained when the interior covering ratio was in the range of 45 to 85%.

The air-flow-direction lengths h1 and h2 of the inner circumferential wall **52** and the outer circumferential wall **53** were changed to differ from each other by 0 mm, 5 mm, 10 mm and 15 mm so as to measure a relationship between wind flow and noise. As shown in FIG. **11**, the noise was reduced and the wind flow was increased when the air-flow-direction lengths h1 and h2 differed from each other as compared to when the air-flow-direction lengths h1 and h2 were equal. Especially, when the difference between h1 and h2 was 5 mm or 10 mm, the noise was the most reduced with the same wind flow. In FIG. **11**, a scale unit of the vertical axis of the graph is 1 dBA and a scale unit of the horizontal axis is 10 m^3/min.

While the air-flow-direction length of the outer circumferential wall **53** was maintained to be larger than the air-flow-direction length of the inner circumferential wall **52** by 10 mm, a covering ratio of the outer circumferential wall **53** relative to the air-flow-direction downstream side end of the cooling fan **21** (hereinafter referred to as an exterior covering ratio) was changed so as to measure a relationship between the exterior covering ratio, wind flow and noise.

As shown in FIG. **8**, "the exterior covering ratio" is defined as a percentage (%) of h6/h3 when h6 is obtained by subtracting an air-flow-direction length h7 of the cooling fan **21** from the maximum air-flow-direction length h3 of the cooling fan **21**. The air-flow-direction length h7 of the cooling fan **21** is the air-flow-direction length of the air-flow-direction downstream side end of the cooling fan **21** extending from the air-flow-direction downstream side end of the outer circumferential wall **53**.

As shown in FIG. **12**, it was found that the wind flow was the largest when the exterior covering ratio was in the range of 55 to 95%. In FIG. **12**, a scale unit of the vertical axis of the graph is 10 m^3/min.

To increase the wind flow, the exterior covering ratio is preferably in the range of 55 to 95%, more preferably 70 to 80%.

To reduce the noise, on the other hand, the exterior covering ratio is preferably in the range of 70 to 95% as shown in FIG. **13**. In FIG. **13**, a scale unit of the vertical axis of the graph is 0.5 dBA.

As shown in FIG. **14A**, when the air-flow-direction downstream side end of the outer circumferential wall **53** was positioned at a farther downstream position in the air flow direction than the air-flow-direction downstream side end of the cooling fan **21**, the flow of air radially discharged from the cooling fan **21** is interrupted, and the flow speed of air passing through the space **55** provided between the inner circumferential wall **52** and the outer circumferential wall **53** is reduced. Also, the air that radially flows from the fan collides with the outer circumferential wall **53**, so that the air is partially delivered into the space. Presumably because of the above, a negative pressure is not easily generated within the space **55** when the exterior covering ratio exceeds 100%.

On the other hand, as shown in FIG. **14**B, when at least the air-flow-direction downstream side end of the outer circumferential wall **53** is positioned at a further upstream position in the air flow direction than the air-flow-direction downstream side end of the cooling fan **21**, the flow of air presumably passes through the space **55** with a certain speed, thereby generating a negative pressure within the space **55**.

From the above, the following findings have been made with respect to the relationship between the interior covering ratio of the inner circumferential wall **52**, the exterior covering ratio of the outer circumferential wall **53**, the wind flow and the noise:

- the difference between the air-flow-direction length h1 of the inner circumferential wall **52** and the air-flow-direction length h2 of the outer circumferential wall **53** is preferably 5 to 10 mm to reduce the noise with the same air volume;
- the exterior covering ratio of the outer circumferential wall **53** is preferably 55 to 95% in terms of increase in the wind flow, the exterior covering ratio is more preferably 70 to 95% in terms of reduction in the noise, and the exterior covering ratio is more preferably 70 to 80% in terms of increase in the wind flow; and
- the interior covering ratio of the inner circumferential wall **52** is preferably 45 to 85% to increase the air volume.

[Characteristics of Cooling Unit **20**]

(1)

The cooling unit **20** for a construction machine, which is a cooling device for use in the hydraulic excavator **1**, includes: the cooling fan **21**; the shroud **40** for covering the outer circumferential side of the cooling fan **21**; and the space **55** having the inner circumferential wall **52** that is provided on the shroud **40** and adjacent to the outer circumference of the cooling fan **21**. The space **55** increases the flow of air blown by the cooling fan **21**, by generating the negative pressure with the air discharged from the cooling fan **21**. The air-flow-direction downstream side end of the outer circumferential edge of the cooling fan **21** is positioned at a further downstream position in the air flow direction than the air-flow-direction downstream side end of the inner circumferential wall **52**.

In the cooling fan **20**, the negative pressure is generated in the space **55** when the cooling fan **21** is rotated to flow air, so that the flow of air blown by the cooling fan **21** is increased. More specifically, when one point within the space **55** is positioned between the vanes **21***a*, air is suctioned by the negative pressure generated therein, and subsequently the air is swept out by the vanes **21***a*. Since the air-flow-direction downstream side end of the outer circumferential edge of the cooling fan **21** is positioned at a further downstream position in the air flow direction than the air-flow-direction downstream side end of the inner circumferential wall **52**, the sufficient amount of air is supplied to the space **55** and the flow of air blown by the cooling fan **21** is increased due to synergistic interaction between the air and the negative pressure within the space **55**. Thus, the flow of air flowing in the vicinity of the cooling core **30** is increased, so that engine cooling performance of the radiator **31** and the like of the cooling core **30** is enhanced.

(2)

When the ratio (percentage) between the air-flow-direction length of the portion covered by the shroud **40** and the inner circumferential wall **52** on the outer circumferential edge of the cooling fan **21** and the whole air-flow-direction length of the cooling fan **21** is referred to as the interior covering ratio, the interior covering ratio is in the range of 45 to 85%. The flow of air blown by the cooling fan **21** is sufficiently increased by setting the interior covering ratio in an appropriate range. Thus, cooling capability is enhanced even when the rotation speed of the cooling fan **21** is the same as conventional. Even when the rotation speed of the cooling fan **21** is reduced, the same cooling capability can be obtained.

(3)

The space **55** is formed by the ring **51**. The ring **51** includes the inner circumferential wall **52** adjacent to the outer circumference of the cooling fan **21** and the outer circumferential wall **53** extending toward the air-flow-direction downstream side further than the inner circumferential wall **52**. The air-flow-direction downstream side end of the outer circumferential edge of the cooling fan **21** is positioned at a further downstream position in the air flow direction than the air-flow-direction downstream side end of the inner circumferential wall **52**. When the cooling fan **21** is rotated to flow air, negative pressure is generated in the space **55** provided between the inner circumferential wall **52** and the outer circumferential wall **53** of the ring **51**. Thus, the flow of air blown by the cooling fan **21** is increased as described above.

(4)

The ring **51** is made from a member different from the shroud **40**. Since the ring **51** is attachable to the shroud **40**, an appropriate ring **51** can be selected suitably for the arrangement of the shroud **40** and the cooling fan **21**.

(5)

The ring **51** includes the annular base **54** for connecting the inner circumferential wall **52** with the outer circumferential wall **53**. Since the ring **51** is an integral member formed by the inner circumferential wall **52**, the outer circumferential wall **53** and the base **54**, it is easy to manufacture and manage the ring **51**.

(6)

The inner circumferential wall **52** and the outer circumferential wall **53** are cylindrical portions extending in parallel to the air flow direction. Thus, it is easy to manufacture the ring **51**.

(7)

The cooling fan **21** is driven to rotate by the engine **6***a* included in a construction machine such as a hydraulic excavator. Since the cooling fan **21** is rotated by the rotation of the engine **6***a*, the arrangement can be simplified.

Second Exemplary Embodiment

Next, a second exemplary embodiment of the invention will be described below. In the following description, the same components as those described above will be indicated by the same reference numerals and the description thereof will be omitted.

In the first exemplary embodiment, the inner circumferential wall and the outer circumferential wall are provided as the annular ring **51** surrounding the cooling fan **21**.

In the cooling device according to the second exemplary embodiment, a plurality of wall components **112** are provided as shown in FIG. **15**, in place of the consecutive ring **51**. More specifically, the wall components **112** are combined around the rotation shaft of the cooling fan **21** to surround the cooling fan **21**, which is different from the first exemplary embodiment.

As shown in FIG. **8** according to the first exemplary embodiment, the wall components **112** respectively include the inner circumferential wall **52** and the outer circumferential wall **53**, and the air-flow-direction downstream side end of the cooling fan **21** is positioned at a further downstream position in the air flow direction than the air-flow-direction downstream side end of the inner circumferential wall **52**.

The interior covering ratio is in the range of 45 to 85%, preferably 60 to 70% as in the first exemplary embodiment.

The wall components **112** are laid around the rotation shaft of the cooling fan **21** on an outer surface of the case **41** of the shroud and are fixed by a bolt, an adhesive or weld.

Incidentally, although a slight clearance is provided between adjacent wall components **112**, cooling efficiency as described in the first exemplary embodiment is hardly impaired because substantially the whole outer circumference of the cooling fan **21** is surrounded by the inner circumferential wall **52** and the outer circumferential wall **53** of each of the wall components **112**. To ensure the efficiency more reliably, the clearance between the adjacent wall components **112** may be filled in with a joint member, paste or weld after fixing the case **41** of the wall components **112**.

While FIG. **11** shows four wall components, the number of the wall components is not limited thereto but may be approximately two to six.

According to the second exemplary embodiment, even when the cooling device includes a large cooling fan **21** used for a large construction machine, the inner circumferential wall **52** and the outer circumferential wall **53** can be formed to surround substantially the whole circumference of the cooling fan **21**.

Other Exemplary Embodiments

Though the exemplary embodiments of the invention have been described above, the invention is not limited thereto, but includes modifications as long as such modifications are compatible with the invention.

(A)

Though the ring **51** is a single annular member in the first exemplary embodiment, the invention is not limited thereto. The ring may be formed by annularly arranging inner circumferential walls and outer circumferential walls consecutively by combining a plurality of members. For example, as shown in FIG. **17**, a consecutive ring can be formed by combining ends of two semi-annular members **113** each having the inner circumferential wall **52** and the outer circumferential wall **53**.

(B)

In the above-described exemplary embodiments, the inner circumferential wall and the outer circumferential wall extend in parallel in the air flow direction. However, the invention is not limited thereto.

For example, a ring **61** shown in FIG. **17** includes an inner circumferential wall **62**, an outer circumferential wall **63** and a base **64**. The inner circumferential wall **62** is positioned on the edge of the opening of the case **41**. The outer circumferential wall **63** is positioned at a further radially outward position than the inner circumferential wall **62**, and an annular space **65** is provided therebetween. The inner circumferential wall **62** and the outer circumferential wall **63** are concentric to define a trumpet shape (a bottom-widened shape) of which a diameter increases as extending to the downstream side in the air flow direction. Incidentally, only either one of the inner circumferential wall and the outer circumferential wall may have a trumpet shape.

In such an exemplary embodiment, the same advantages can be attained as in the above-described exemplary embodiments. Further, this exemplary embodiment can reduce the noise by suppressing turbulence.

(C)

For example, a ring **71** shown in FIG. **18** includes an inner circumferential wall **72**, an outer circumferential wall **73** and a base **74**. The inner circumferential wall **72** is positioned on the edge of the opening of the case **41**. The outer circumferential wall **73** is positioned at a further radially outward position than the inner circumferential wall **72**, and an annular space **75** is provided therebetween. The inner circumferential wall **72** and the outer circumferential wall **73** are concentric to extend in parallel in the air flow direction. Specifically, a taper portion **72*a*** is provided on a distal end of the inner circumferential wall **72**. A taper portion **73*a*** is provided on a distal end of the outer circumferential wall **73**. The diameters of the taper portions **72*a*** and **73*a*** gradually increase toward the downstream side in the air flow direction. Incidentally, only either one of the inner circumferential wall and the outer circumferential wall may have the taper portion.

In such an exemplary embodiment, the same advantages can be attained as in the above-described exemplary embodiments. Further, this exemplary embodiment can reduce the noise by suppressing turbulence.

(D)

In the above-described exemplary embodiments, the inner circumferential wall and the outer circumferential wall are formed by an integrated member.

However, the invention is not limited thereto.

For example, a ring **81** shown in FIG. **19** is formed by two separate members of an inner circumferential wall **82** and an outer circumferential wall **83**. An annular space **85** is provided between the inner circumferential wall **82** and the outer circumferential wall **83**. The inner circumferential wall **82** includes a cylindrical portion **82*a*** and a fixed portion **82*b***. The fixed portion **82*b*** is fixed to the case **41** by a bolt or weld. The outer circumferential wall **83** includes a cylindrical portion **83*a*** and a fixed portion **83*b***. The fixed portion **83*b*** is fixed to the case **41** of the shroud **40** by a bolt or weld.

In such an exemplary embodiment, the same advantages can be attained as in the above-described exemplary embodiments.

(E)

In the above-described exemplary embodiments, the inner circumferential wall and the outer circumferential wall are formed by members different from the shroud. However, the invention is not limited thereto.

For example, a ring **91** shown in FIG. **20** is formed by an inner circumferential wall **92** formed by bending the inner circumferential edge of the case **41** and an outer circumferential wall **93**. An annular space **95** is provided between the inner circumferential wall **92** and the outer circumferential wall **93**. The outer circumferential wall **93** includes a cylindrical portion **93*a*** and a fixed portion **93*b***. The fixed portion **93*b*** is fixed to the case **41** of the shroud **40** by a bolt or weld.

In such an exemplary embodiment, the same advantages can be attained as in the above-described exemplary embodiments.

(F)

The ring may be integrated with the shroud according to an aspect of the invention. As shown in FIG. **21**, a ring **101** is integrated with the case **41** of the shroud. An inner circumferential wall **102** is provided on the inner circumferential edge of the case **41** and an outer circumferential wall **103** is provided on the outer surface of the case **41**. Further, a space **105** for generating negative pressure is provided between the inner circumferential wall **102** and the outer circumferential wall **103**.

In such an exemplary embodiment, the case **41** of the shroud and the ring **101** may be made of resin by a method such as injection molding. Such a shroud is favorably adoptable for a small construction machine which only requires a certain level of durability.

In such an exemplary embodiment, the same advantages can be attained as in the above-described exemplary embodiments. Further, the load of assembling work can be reduced by reduction of the number of parts, and the weight of a construction machine can be reduced.

(G)

In the above-described exemplary embodiments, the cooling fan **21** is exemplarily rotated directly by the engine **6***a* as shown in FIG. **4**. However, the invention is not limited thereto.

For example, the cooling fan may be rotated by a hydraulically-actuated motor provided in the vicinity of the cooling core such as the radiator.

Such an arrangement can be designed without concern for influence by vibration of the engine unlike an arrangement for the cooling fan rotated directly by the engine. Thus, the clearance G between the cooling fan **21** and the inner circumferential wall **52** of the ring **51** provided on the shroud **40** can be minimized. Consequently, air in the vicinity of the shroud **40** can flow more smoothly, thereby reducing the noise and enhancing cooling efficiency of the cooling core.

Alternatively, the cooling fan may be rotated by an electric motor.

(H)

In the above-described exemplary embodiments, the intake cooling unit **20** is exemplarily used, in which the cooling fan **21** is provided on the downstream side of the cooling core **30** in the air flow direction as shown in FIG. **4**. However, the invention is not limited thereto.

For example, as shown in FIG. **22**, the invention is applicable to a so-called blowoff cooling unit **20** for sending air from the engine **6***a* to the cooling core **30** such as the radiator by the cooling fan **21**.

In other words, even in the blowoff cooling unit **20**, wind flow is increased as in the first exemplary embodiment by providing the ring **51** within the shroud **40**, so that the cooling core **30** can be efficiently cooled and the noise can be reduced.

(I)

In the above-described exemplary embodiments, the cooling fan **21** is exemplarily described as an axial-flow fan as shown in FIG. **6**. However, the invention is not limited thereto.

For example, the cooling unit may include other blast fan such as a sirocco fan and an obliquely axial-flow fan.

(J)

In the above-described exemplary embodiments, the radiator **31**, the oil cooler **32** and the aftercooler **33** are exemplarily used as a heat exchanger of the cooling core **30**. However, the invention is not limited thereto.

For example, only radiator may be used as a cooling core positioned opposite to the cooling fan according to the aspect of the invention. Alternatively, other heat exchangers may be used alone or in combination.

(K)

In the above-described exemplary embodiments, the hydraulic excavator **1** is exemplarily described as a construction machine including the shroud **40** of the cooling fan **21** according to the aspect of the invention as shown in FIG. **1**. However, the invention is not limited thereto.

For example, the invention is also applicable to other construction machine such as a wheel loader or work machine such as a forklift in addition to the hydraulic excavator.

(L)

The above-described exemplary embodiments may be adopted alone or in combination.

The invention claimed is:

1. A cooling device, comprising:

a cooling fan;

a shroud provided at an outer circumferential side of the cooling fan;

an inner circumferential wall provided on the shroud and spaced apart from an outer circumference of the cooling fan in a radial direction of the cooling fan by a predetermined distance to surround the cooling fan, the inner circumferential wall being outside of and facing the cooling fan in the radial direction of the cooling fan; and

an outer circumferential wall provided to surround the inner circumferential wall, the outer circumferential wall being outside of and facing the inner circumferential wall in the radial direction of the cooling fan, an air-flow-direction downstream side end of the outer circumferential wall being positioned downstream, in an air flow direction, of an air-flow-direction downstream side end of the inner circumferential wall, at least a portion of the outer circumferential wall including a cylindrical surface,

wherein the cooling fan is rotatable in a space on a radially inner side of the inner circumferential wall,

wherein an air-flow-direction upstream side end of the cooling fan is positioned upstream, in the air flow direction, of an air-flow-direction upstream side end of the inner circumferential wall and an air-flow-direction upstream side end of the outer circumferential wall,

wherein the air-flow-direction downstream side end of the outer circumferential wall is positioned upstream, in the air flow direction, of an air-flow-direction downstream side end of an outer circumferential edge of the cooling fan, and

wherein an exterior covering ratio is in a range of 55 to 95%, the exterior covering ratio being a ratio of (i) an air-flow-direction length of a portion of the cooling fan covered by the shroud and the outer circumferential wall to (ii) a maximum air-flow direction length of the cooling fan in the air flow direction of the cooling fan.

2. The cooling device according to claim **1**, wherein at least one of the inner circumferential wall and the outer circumferential wall is a ring that is consecutively provided around a rotation shaft of the cooling fan.

3. The cooling device according to claim **1**, wherein the exterior covering ratio is in a range of 70 to 95%.

4. The cooling device according to claim **3**, wherein the exterior covering ratio is in a range of 70 to 80%.

5. The cooling device according to claim **1**, wherein an interior covering ratio is in a range of 45 to 85%, the interior covering ratio being a ratio of (i) an air-flow-direction length of a portion of the cooling fan covered by the shroud and the inner circumferential wall to (ii) the maximum air-flow-direction length of the cooling fan in the air flow direction of the cooling fan.

6. The cooling device according to claim **1**, wherein at least one of the inner circumferential wall and the outer circumferential wall is integrated with the shroud.

7. The cooling device according to claim **1**, wherein at least one of the inner circumferential wall and the outer circumferential wall is formed by a member different from the shroud.

8. The cooling device according to claim **7**, further comprising:

an annular base connecting the inner circumferential wall to the outer circumferential wall.

9. The cooling device according to claim **1**, wherein at least one of the inner circumferential wall and the outer circumferential wall includes a cylindrical portion extending in parallel to the air flow direction.

10. The cooling device according to claim **1**, wherein at least one of the inner circumferential wall and the outer circumferential wall includes a diameter-expanded portion of which an inner diameter increases toward downstream in the air flow direction.

11. A construction machine or a work machine, comprising the cooling device according to claim **1**.

12. The cooling device according to claim **1**, wherein the cylindrical surface is radially spaced apart from the cooling fan and curved to correspond to the radial curvature of the outer circumferential edge of the cooling fan.

13. The cooling device according to claim **1**, wherein at least a portion of the cylindrical surface tracks the radial curvature of the outer circumferential edge of the cooling fan.

14. The cooling device according to claim **13**, wherein the entire cylindrical surface tracks the radial curvature of the outer circumferential edge of the cooling fan.

15. The cooling device according to claim **1**, wherein the inner circumferential wall and the outer circumferential wall define an annular space therebetween that surrounds the cooling fan.

16. The cooling device according to claim **1**, wherein the cylindrical surface of the outer circumferential wall surrounds an entire circumference of the inner circumferential wall.

17. The cooling device according to claim **1**, wherein each of the inner circumferential wall and the outer circumferential wall is a ring that is consecutively provided around a rotation shaft of the cooling fan.

* * * * *